Report No. 77-1-6

October, 1976

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## Pilot Control Project Using Trichlorfon and *Bacillus thuringiensis* Against Forest Tent Caterpillar in Southwest Alabama

U. S. Department of Agriculture - Forest Service, Southeastern Area, State and Private Forestry, Forest Insect and Disease Management

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# Pilot Control Project Using Trichlorfon and *Bacillus thuringiensis* Against Forest Tent Caterpillar in Southwest Alabama

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## ACKNOWLEDGEMENTS

Appreciation is extended to the following for their assistance in setting up the project and actual help in the field work:

Bob Morris and Lonnie Newsome from the Southern Forest Experiment Station; Gerry Hertel of the Alexandria Field Office, State and Private Forestry; John Niesses and Dick Orchard of the Pacific Northwest Experiment Station; Jerry Moss and Paul Cummingham of Auburn University; Bill Ciesla and Harold Flake of State and Private Forestry, Region One; and Tom Hofacker, State and Private Forestry, Washington, D.C. office.

Many other persons were involved in various aspects of the field work and the project and their assistance is appreciated.

Special thanks is extended to International and Scott Paper Companies for providing use of their lands, personnel and boats during the spray application and to IPC for the use of their cabin and landing at Hastie Lake.

Even though they did not provide much assistance, we must acknowledge the many cottonmouth moccasins and other swamp critters that added to the interest of the project and kept things lively.

Front Cover: Two constant companions during the Project in the swamp - the cottonmouth moccasin and the forest tent caterpillar. Photo credit for the cover photo, and figures 1, 2, 3, 5 and 8 go to James Harper. Remaining photos were provided by the U.S.F.S.

## INTRODUCTION

The forest tent caterpillar, Malacosoma disstria Hubner, (Figure 1) has been epidemic in swamp lands of water tupelo, Nyssa aquatica L., (swamp tupelo), and blackgum, Nyssa sylvatica var. biflora (Walt.) Sarg., in southern Louisiana and Alabama for many years (Morris, 1965). Over the past 5 years, tupelo and blackgum have been partially to completely defoliated by the forest tent caterpillar on approximately 500,000 acres/year in Louisiana and 50,000 acres/year in Alabama. In 1969, an impact study was initiated by the Southern Forest Experiment Station to determine the effects of tent caterpillar defoliation on increment growth of water tupelo. The study was located in the Mobile-Tensaw River Basin, near Mobile, Alabama. Preliminary results of the study have shown that water tupelo completely defoliated by forest tent caterpillar sustained an average increment growth loss of approximately 45 percent in the spring of 1975. Stand volume tables were developed by the Resource Use and Management Unit, Southeastern Area for this timber type so that increment data can be converted to cubic foot volume for use in calculating cost/benefit ratios.

Since 1968, various chemical and biological pesticides have been tested for control of forest tent caterpillar in southwest Alabama. 1/2/3/4/ Trichlorfon (Dylox(R)) was highly effective against the forest tent caterpillar on 20 acre plots (Abrahamson and Morris, 1974), and was registered by the Environmental Protection Agency for this use in 1972.

Figure 1: Forest tent caterpillar, (Malacosoma disstria Hubner), the target insect for the pilot control project in the Mobile-Tensaw River Basin, Alabama, 1975.

Bacillus thuringiensis (B.t.) was also shown to be highly effective against the forest tent caterpillar on small plots (Abrahamson and Harper, 1973) and was recently registered for aerial application.

In the fall of 1974, the Alabama Forestry Commission requested the cooperation of the U.S. Forest Service in pilot testing trichlorfon and B.t. against the tent caterpillar in the Mobile-Tensaw River Basin. Local landowners had consulted the Alabama Forestry Commission regarding the possibility of treating the area of infestation. The Commission in turn requested that the U.S.F.S. investigate the feasibility of conducting large scale control projects in the area. A cooperative pilot control project was established by the U.S.F.S., Alabama Forestry Commission, Auburn University, and Scott and International Paper Companies to investigate the effectiveness and environmental impact of candidate materials when applied on an operational basis. The State is expected to request an operational spray project if forest tent caterpillar populations remain at an epidemic level, the cost/benefit ratios favor such an action, and trichlorfon or B.t. proves both efficacious and environmentally acceptable during the pilot study.

The objectives of this pilot project were to: (1) determine if the registered rates of trichlorfon and B.t. would significantly prevent forest tent caterpillar defoliation on large scale plots and (2) determine the environmental impact of trichlorfon and B.t. on selected non-target organisms in the Mobile-Tensaw River Basin.

## METHODS

### Plot Selection

Criteria for plot selection included: (1) A similar past history of defoliation by the forest tent caterpillar based on amount of defoliation over the last 10 years; (2) natural boundaries (rivers, lakes, levees, etc.) to minimize reinfestation possibilities from adjacent untreated areas; (3) approximately the same established population levels based on egg mass counts made during plot selection.

Initial field work began in mid-February. Branch samples were shot from trees using .22 magnum rifles and hollow point bullets (Figure 2) to determine potential larval populations based on the numbers of egg masses per branch (Abrahamson and Harper, 1973). Three areas of approximately 1,000 acres and one area of approximately 500 acres having sufficient potential forest tent caterpillar populations based on egg mass counts were deliniated. Compass lines were flagged to mark boundary lines when natural or obvious boundaries such as rivers or powerlines could not be usec

Corners of all plots were marked for pilot orientation by placing panels cut from nylon parachutes in tree tops using the method described by Abrahamson and Harper (1973). An arrow with a nylon fishing line attached was shot over two trees on the corners to be marked. Nylon parachute

cord was tied to the fishing line and pulled over the trees. The parachute panel was then attached to the cord, pulled up and positioned between the tops of the trees (Figure 3) and tied securely in a position that would be visable from the spotter and spray planes.

One 1,000 acre plot received no treatment and served as the control or check plot. One was treated with 24 ounces per acre of a 4 lb. active formulation of trichlorfon and is hereafter referred to as the Dylox plot. The third 1,000 acre plot was treated with 0.5 pounds of Dipel(R) (3.6 billion international units) per acre and is hereafter referred to as the Dipel I plot. The 500 acre plot was treated with two applications of Dipel(R), each at the above rate and approximately a week apart and will be referred to as the Dipel II plot.

The Dylox plot (Figure 4) was located in a bend of the Tensaw River near Stockton, Alabama in Baldwin County. Starting at Sandy Hook, past the outlet of Briar Lake, past Bryant's lower landing on boat shore and to the middle of the bend north of Hastie Lake, it was approximately 900 acres surrounded on three sides by the Tensaw River. The east branch of the "T" in Mifflin Lake provided access to the west side of the Dylox spray plot. This area had an average egg mass count of 4.00 per branch sample based on the sampling methods of Abrahamson & Harper, (1973). Normally, 2.5 egg masses per branch sample means that complete defoliation can be expected.

Figure 2: Shooting branch samples to determine egg mass counts for establishing treatment plots.

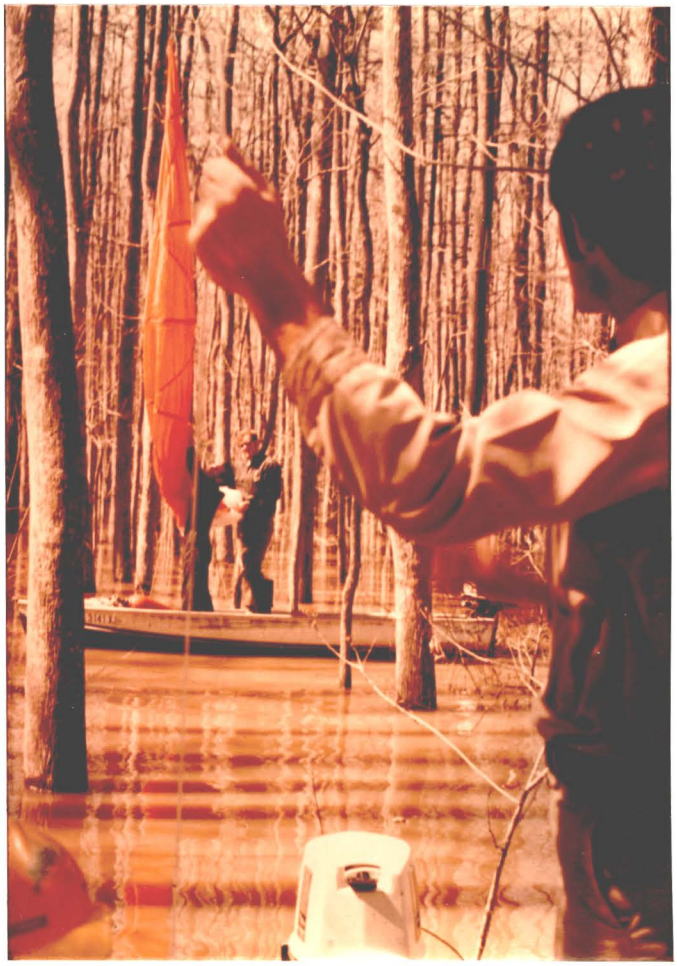

Figure 3: Hoisting a nylon parachute panel to mark the corners of the spray plots.

The Dipel I plot (Figure 4) was located between Middle River on the east boundary and Bayou Zeast on the west boundary with the old powerline serving as the south boundary and the new powerline serving as the north boundary. This plot was approximately 1,000 acres with access on all sides. This area had an average egg mass count of 8.06 per branch sample.

The Dipel II plot (Figure 4) was located next to the Dipel I plot between Bayou Zeast on the east and south boundaries, the Mobile River on the west boundary and the new powerline as the north boundary. This plot was approximately 500 acres with access on all sides. This area had an average egg mass count of 6.27 per branch sample.

The control plot (Figure 4) was located north of the Dipel plot and west of the Dylox plot between the Middle River on the west, Bottle Creek on the east and Alligator Lake and Dominic Creek on the north. A line drawn due west from the outlet of Lower Fisher Lake on Bottle Creek served as the south boundary. This plot had a total acreage of 1,000 acres and an average egg mass count of 5.24 per branch sample.

The control plot was located so as to minimize the possibility of water contamination from the sprayed plots. The Dipel II plot was located next to the Dipel I plot to facilitate the application of B.t. Defoliation and effects of spraying on non-target organisms were measured on each of these plots.

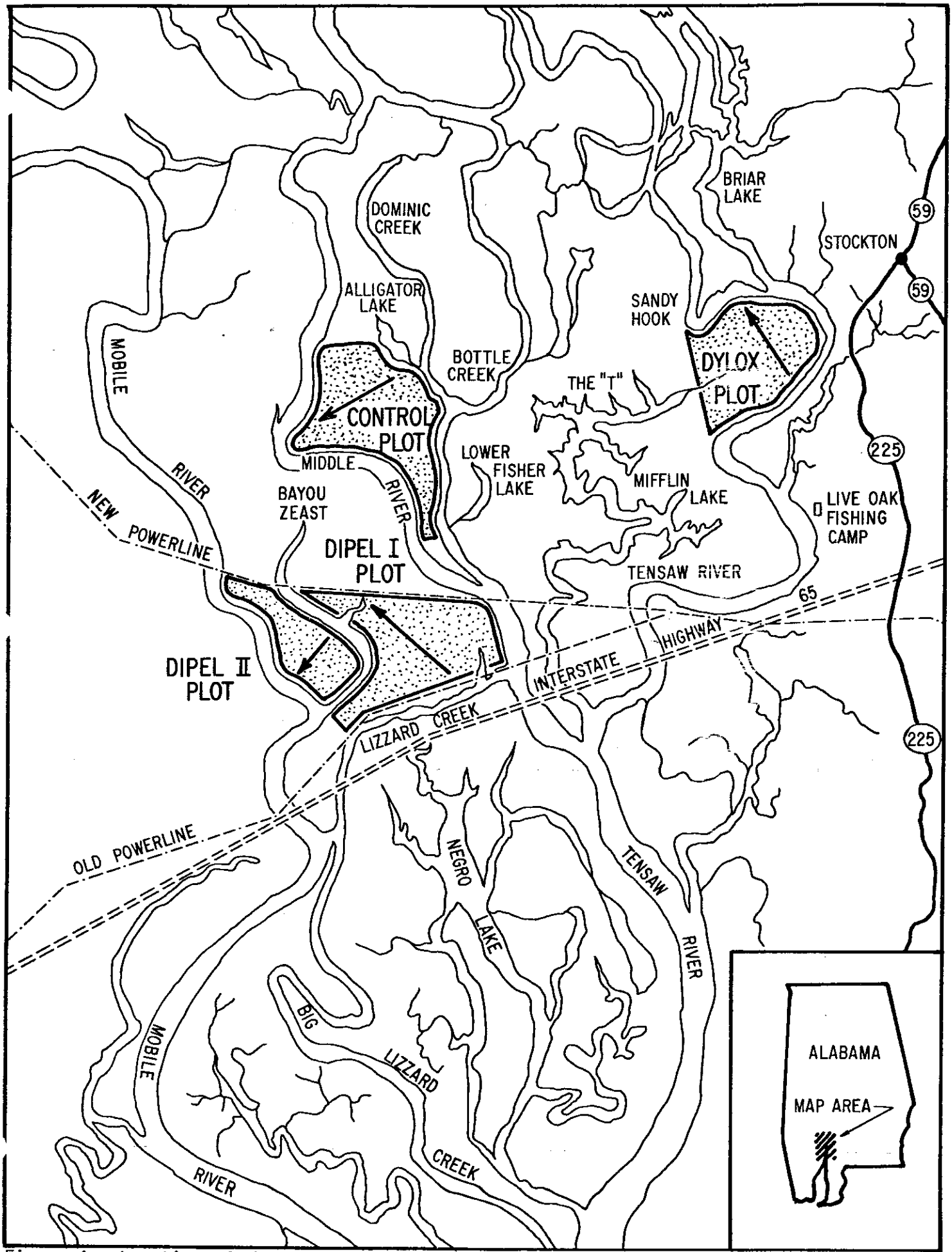


Figure 4: Location of the forest tent caterpillar control project plots in the Mobile-Tensaw River Basin, Alabama, 1975

Subplot Selection

A diagonal line was run through each of the four plots (Figure 4). Twenty (20) sub-plots were located systematically along each line (Figure 5). The first and last sub-plots were at least 500 feet from the plot boundary to avoid any "edge effect". Three dominant and/or co-dominant water tupelo or black gum trees were selected and individually marked and identified with tree marking paint on each sub-plot for a total of 60 sample trees per plot.

Determination of Optimal Spray Date:

Beginning in early March, branch samples were taken approximately twice each week to determine the initial hatch date and to monitor subsequent larval development. Treatment of the plots was to have begun when the insects were in the second instar and/or the tupelo leaf expansion was at least one-half complete. Several problems initiated by delays in project approval and funding, coupled with an unusually early spring, combined to delay optimal timing of all treatments. Treatments were applied against third and fourth instar larvae, and although most leaves were fully expanded, the canopies were 40-80% defoliated at time of spraying.

Aerial Application

Materials and formulations used in the project are as follows:

Trichlorfon (Dylox$^{(R)}$ 4)*

(.75/lb. AI/A) (24 fl. of Dylox$^{(R)}$ 4/acre + Rhodamine B Extra Base**)

Figure 5: Establishing subplots within the spray plots.

B.t. (Dipel(R) WP) *** 1 application
(3.6 BIU/Acre **** (1/2 lb. Dipel(R) WP in 1 gal. of water/acre) + Rhodamine B Extra F ** and 8 oz. of Chevron Spray Sticker

B.t. (Dipel(R) WP) 2 applications
(3.6 BIU/A) (1/2 lb. Dipel(R) WP in 1 gal. of water/acre) + Rhodamine B Extra F (in first application only) and 8 oz. of Chevron Spray Sticker.

Control - No treatment

Dylox(R) 4 was pumped directly into the spray tank of the aircraft from the shipping containers. The dye was added and agitated with the airplane's recirculation system.

Dipel(R) WP was mixed with water, dye, and spray sticker in two 300 gallon mixing tanks equipped with agitators and recirculation apparatus (Figure 6). When needed, it was pumped directly into the aircraft spray tank.

* Chemagro Company

** Rhodamine B Extra Base (General Analine Film Corp.) was formulated in tetrahydro-furfuryl alcohol. Both dyes were added at the rate of 3.78 grams per gallon at 0.1% (wt/vol) of final spray.

*** Abbot Laboratories

**** BIU = billion international units of potency.

Personnel from the Pacific Northwest Forest and Range Experiment Station assisted with calibration, swath width determination, droplet spectrum determination and adjustment, and deposit assessment. Swath width and droplet spectrum was determined by placing kromecoat cards at intervals on open ground near the airstrip and spraying them with complete formulations at operational spray height (30-50 feet) and airspeed (150 mph).

Local meteorological data was obtained through the U.S. Weather Bureau located at the Mobile Municipal Airport. One day and five day extended forecasts were used to determine optimal spray conditions. Portable meteorological instruments were set up at the loading site to monitor wind speed and direction, temperature and humidity. The loading site was located at Bay Minette Municipal Airport, approximately 10 miles from the spray plots.

Trichlorfon and B.t. (Dipel I and 1st application of Dipel II) were applied by a twin engine fixed-wing aircraft (DC-3) with a five hundred (500) gallon carrying capacity (Figure 7). The nozzles used for the trichlorfon treatment were Spraying Systems(R) diaphragm check valves with teejet flat fan 8010 spray tips.* Twelve nozzles were used, six along the trailing edge of each wing concentrated aft of

* Optimal nozzle size and configuration were determined by John Neisses and Richard Orchard of the PNW Experiment Station, Corvallis, Oregon.

Figure 6: Three-hundred gallon mixing tanks and recirculating apparatus and pumps used in mixing Bacillus thuringiensis formulation.

Figure 7: Aerial application of trichlorfon over Tensaw-Mobile River Swamp using DC-3 aircraft. Note red dye in spray.

the engine area. The nozzles were oriented straight down or 90° to the line of flight. Spray speed was 150 mph., spray pressure was 40 psi., and the expected VMD was 150 microns. The application was made on March 26, 1975, from 5:50 p.m. to 6:45 p.m. The following table gives meteorological data at the airport during the trichlorfon spraying.

| | Wind | | | Temp | | |
|---|---|---|---|---|---|---|
| Time | Direction | Speed | Gusts | Wet | Dry | Humidity |
| 5:50 pm | 70-90° | 8 mph | frequent to 10 | 55 | 74 | 27% |
| 6:00 | 70-100° | 6-10 | frequent | 54 | 73 | 27% |
| 6:10 | 85-105° | 3-5 | No | 54 | 70 | 34% |
| 6:30 | 100° | 4-5 | No | 54 | 69 | 36% |
| 6:45 | 90-100° | 4-6 | No | 53 | 67 | 38% |

Nozzles used for the B.t. treatment were the same type and size as for the trichlorfon treatment. Sixty nozzles were initially evenly spaced throughout the boom, 30 on each side of the fuselage. Through calibration tests, it was determined that the pressure and flow was reduced on the outboard part of the boom, most likely due to the small, 1" boom. As a result, 8 more nozzles were added; 4 to each side, concentrating them behind the engine area. The nozzles were oriented down and back about 30° to the line of flight. Spray speed was 150 mph, spray pressure was 40 psi, and expected VMD was 250 microns. Application was made on March 31, 1975, from 7:20 a.m. to 8:50 a.m.

The following table gives meteorological data at the airport during the B.t. spraying:

| | Wind | | | Temp | | |
|---|---|---|---|---|---|---|
| Time | Direction | Speed | Gusts | Wet | Dry | Humidity |
| 7:20 AM | 30° | 3 mph | Light | 39 | 43 | 69% |
| 7:40 | 30° | 2-6 | 10 | 42 | 45 | 78% |
| 8:05 | 20-60° | 5-7 | 10 | 40 | 45 | 65% |
| 8:20 | 20-40° | 6-8 | 10 | 40 | 45 | 65% |
| 8:50 | 4-80° | 5-7 | To 9 | 42 | 47 | 66% |

At the time of spraying of both treatments, an observer was present in an Alabama Forestry Commission plane (STL 180) to direct the spray plane to the treatment plots and monitor the application. Radio communication was maintained between the chase plane and the spray plane, airport, and ground flight line marking crews. Swath widths were marked by helium filled balloons raised above the tree tops from boats on the river.

The second application of B.t. on the Dipel II plot was made on April 7, 1975. Two Piper Pawnee aircraft with 150 gal. capacity, fitted with 10 Roto-spin(R) nozzles and calibrated to deliver one gallon per acre were used to make this applications.

## Evaluation

Defoliation Assessment: The USFS, Forest Insect and Disease Management Group was responsible for collecting data to determine the effects of the

treatments on the forest tent caterpillar. Since it is difficult to estimate the numbers of actual populations and, consequently, the effect of the treatments on numbers of individuals, an estimate of effect was based on defoliation before treatment, and defoliation and refoliation after treatment. Defoliation and refoliation on treated and control plots were estimated on individual sample trees from the ground and on an overall plot basis by using low level aerial photos.

Percent defoliation on individual subplot trees was ocularly estimated from the ground (or water during flood periods) within 4 days of spraying and at weekly intervals after spraying. The same individual made all estimates throughout the test in order to reduce variation. Data was recorded as percent defoliation per tree on each sampling date.

Aerial Estimates: At the time of approximate peak defoliation; 35 mm infrared aerial photographs were taken of the plots to determine the extent of defoliation, and refoliation of the plots. Three weeks later, approximately 1 month after application, 9 x 9 infrared aerial photos of the plots were taken by the Alabama Forestry Commission using a Wild RC-10 aerial camera. Evaluation of these photos indicated the overall effectiveness of the sprays in reducing or stopping tent caterpillar defoliation and clearly showed any skips that may have occurred during aerial application. 5/

Spray Deposit Assessment

Spray droplet size and distribution assessment was determined by John Neisses and Richard Orchard, PNW Experiment Station, Corvallis, Oregon. Droplet size spectrum and swath width were determined by placing kromecoat cards at intervals on open ground near the airstrip and spraying over them at the time of actual operational spraying. Within 16 hours following treatment, sample foliage was collected by shooting branches from the tops of dominant trees on the subplots in each pond and catching them before they went under water. Foliage and cards were taken to Corvallis where droplet spectrum and deposit assessment were completed.

Non-target Organism Monitoring

Effects of trichlorfon and B.t. on mammals, birds, fish, crustacea, insects, other arthropods, phytoplankton, and zooplankton were evaluated. The techniques for this phase of the study will be presented in reports by various cooperators. These reports will be prepared and attached as a supplimental of the pilot study final report. Basically these evaluations included effects of trichlorfon and B.t. on: (1) turkeys by feeding studies (Dr. Keith Causey of Auburn University); (2) all types of wildlife by transects run immediately after spraying of these treatments (James Davis, Game and Fish Division, Alabama Department of Conservation and Natural Resources); (3) on caged native fish (brim) in the plots by comparing residue analyses (Larry Johnson, Game and Fish Division, Alabama Department of Conservation and Natural Resources);

(4) on fish food micro-organisms present in plots by comparing populations (Dr. John Lawrence of Auburn University); (5) on non-target terrestrial invertebrates present in plots by determining losses from acute toxicity due to spray material (Dr. James Harper, Auburn Univeristy); (6) on crustacea in the Mobile Bay by determining amounts of trichlorfon that would have an adverse effect (the Marine Resources Division, Alabama Department of Conservation and Natural Resources); (7) on small mammals, birds, and reptiles by comparing residue analyses in pre- and post-spray samples (William Thomas, U.S. Fish and Wildlife Service, Department of Interior).

## RESULTS & DISCUSSION

Defoliation estimates on the Dylox plot were taken one day prior to the spray date. At that time, the Dylox plot had 41% defoliation. This was approximately the same level of estimated defoliation as in the other plots, which ranged from 34-41 percent on March 25 (Table 1). Treatment was applied on March 26. By April 1, the plot defoliation was estimated to be 50 percent. Recovery and refoliation began after that date. At five weeks following treatment the trees had an average defoliation of only 19 percent (Table 1). High winds and light showers prevented application of B.t. until five days later (March 31, 1975). Defoliation estimates taken 3 days prior to treatment in the Dipel I plot averaged 65%. Estimates taken 24 hours following application of B.t. showed an average defoliation of 76% in the Dipel I plot and 58% in the

Dipel II plot (Table 1). Defoliation increased in both Dipel plots following treatment. Ten percent additional defoliation occurred before recovery began. The Dipel II plot that received two applications of insecticide showed a lower level of both pre- and post- treatment defoliation and a faster rate of recovery. The control plot (Figure 8) was almost completely defoliated within two weeks after the Dylox plot had been treated (Table 1). Figure 9 demonstrates the estimated average defoliation and recovery patterns in all plots.

A small amount of streaking occurred in the Dylox plot and pronounced bands of streaking occurred in the Dipel plots (Figures 10 and 11). Streaking in the Dylox plots was undoubtedly due to skipping or spraying error. This was principally due to inability of the spray pilot to maintain visual contact with flight line markers. Streaks in the Dipel plots are more difficult to explain. Spraying error may account for some of the streaking. A 200+ foot effective swath width was expected, however, measurements made on verticle aerial photographs of the plots indicate an average effective swath width of 175' and an interswath center distance of ca. 300 ft. This could account for 125 feet of untreated area between swaths. Lack of foliage in the overstory, due to advanced defoliation at time of spraying and light rain within 10 hours could have prevented the effective distribution and retention of spray that was calculated for the plane and equipment. Also, because winds were slightly higher during the B.t. treatment the spray plane flew at 30 feet above the canopy to reduce drift. This may have reduced effective swath width as well. At the time of application the actual swath widths appeared close to the estimated 200' markers as determined by the observer in the guide plane.

Figure 8: True-color aerial photograph of the control plot for the forest tent caterpillar pilot project on the Mobile-Tensaw River Basin Swamp showing complete defoliation five weeks after insecticides were applied to treatment plots.

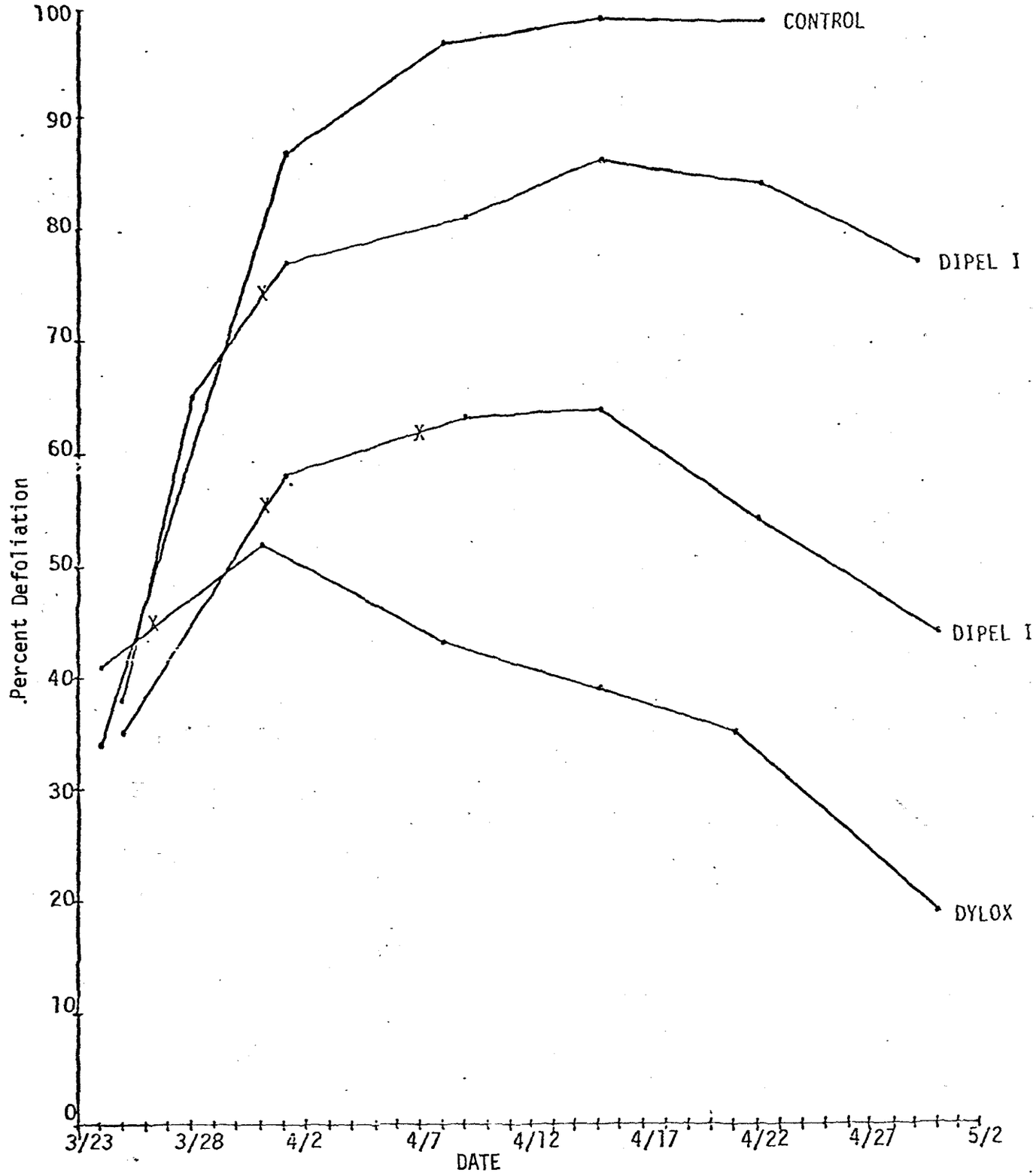


Figure 9 : Estimated average defoliation by forest tent caterpillar and recovery rates of plots treated with trichlorfon (Dylox) and B. thurengiensis (Dipel) in the Tensaw-Mobile River Basin, Alabama, 1975. X marks when treatment was applied.

Figure 10: Infrared aerial photograph taken five weeks after treatment with trichlorfon showing streaking and protection of plot, Mobile Basin, Alabama, 1975. Blue streaks are defoliated areas not protected by insecticide.

Figure 11: Infrared aerial photograph taken four weeks after treatment with Bacillus thuringiensis showing streaking and protection plot, Mobile Basin, Alabama, 1975.

The spray deposit for the trichlorfon indicated that the actual droplet VMD was larger than expected, 175$\mu$ instead of 150$\mu$. The nozzles should have been rotated just slightly forward to achieve the desired 150$\mu$VMD. There were spray deposits on all but 3 subplots and a considerable variance between subplots (Table 2). Spray deposit on branch samples should be a good indication of deposit throughout the plots. It is also possible that the small droplets did not have enough velocity to impinge on the large leaf, but may have landed on smaller surface areas such as the stems, or on the insect itself. If this was not the case, then there should have been streaking on plots B, C, H, I, and T (Table 2). When compared with the estimated defoliation on the actual subplots within the Dylox plot (Table 3), it is found these do not actually coincide with foliage protection. None of the subplots actually occurred in a streaked area, although a few were located on the edge of streaks (especially subplots B, C, & I). The method of determining spray coverage and droplet density is only an approximation based on a small number of samples taken from each subplot.

The spray deposit for B.t. indicated that the actual droplet VMD was 241$\mu$, which was close to the 250$\mu$ VMD expected. A great deal of variance in the number of drops on foliage occurred (Table 4). This indicates that some areas had very little coverage (subplots G, H, K, L, and O) which roughly corresponds to the locations of streaks in the plots and to the highest defoliation estimates (Table 5). This demonstrates the necessity of obtaining good coverage if satisfactory control is to be

obtained with B.t. Rainfall prevented completion of spray assessment sampling in the Dipel II plot and some subplots of the Dipel I plot. Table 6 lists the defoliation estimates for the Dipel II plot. The population within the control plot utilized the available food supply nearly 3 weeks prior to completion of normal larval development (Table 7). This resulted in a population collapse due to starvation as evidenced by egg mass counts made later in the year.

Egg mass counts made in July, 1975 and February and March, 1976 showed averages of 1.26 and 2.14 egg masses on branches in the Dylox and control plots, respectively. Egg mass counts of 3.15 and 2.34 per branch were found in the Diepl I and II plots, respectively. Populations in all plots were thus reduced by 31-41% over the previous year's levels. Because the check plot collapsed, however, it is difficult to say how much of the reduction in the treated areas was due to treatment and how much was due to natural factors. In addition, the immigration rate into these plots is not known.

It should be pointed out that although the populations of forest tent caterpillars collapse in high population areas in the Mobile-Tensaw River Basin, there are sufficient areas of low population to sustain epidemic conditions in the Basin. This chronic epidemic condition is known to have existed for decades. Thus, population collapses will not solve the forest tent caterpillar problem in the Mobile-Tensaw River Basin. If growth losses are to be prevented, directed management of the insect populations will be necessary.

Both materials used in these tests could be used in operational projects for control of forest tent caterpillar in tupelo forests. While the conditions encountered in this project did not allow for application of either material at the optimal date, both controlled the forest tent caterpillar. Trichlorfon gave excellent control and foliage protection. B.t. controlled insects and protected foliage well where it reached the foliage, however, adjustments in application techniques will be required to obtain uniform coverage and complete protection. This seems evident even when the more severe conditions of population pressure and advanced defoliation under which it was tested are considered.

Each material has distinct advantages and disadvantages which should be pointed out. The major factor in favor of the use of Bacillus thuringiensis is its specificity or selectivity. In the particularly sensitive aquantic habitat involved, little imbalance should be occasioned by its use. However, problems in optimal application technology still need to be worked out.

Trichlorfon has advantages which, barring any concern over the use of a chemical insecticide in the area, and its impact on other anthropods, make it the material of choice. It can be applied at one-fifth the volume that B.t. is currently being applied. This allows faster and cheaper application in a situation where timing may be extremely critical, as seen in these tests. Secondly, it kills rapidly. Bacillus thuringiensis

stops feeding damage by this insect as soon as it is ingested, but because larvae do not eat continuously, inactivation or washoff could affect total mortality achieved under certain conditions. In this test, percent foliage loss subsequent to application was approximately equal in all treatments. Material cost was approximately equal for trichlorfon and B.t. in 1975.

Summation of Impact Study Results

Seven separate studies were planned to determine the impact of aerially applied B.t. and trichlorfon on non-target organisms in the water tupelo environment. In general, the impact studies, as presented in the attached supplemental*were negative. Some results are still incomplete, however, a description of the tests and, when possible, preliminary results or observations will be given.

Alabama state fish biologists agreed to collect and cage native fish in treated and untreated areas to determine acute toxicity effects on the fish. High flood water made collecting of game species impossible during the entire test period. Actual observations by these biologists indicated no acute toxicity, as evidenced by abnormal fish mortality, occurred in any treated areas within 24 hours of application.

* Supplementals will not accompany all copies of the report, but will be available upon request from the U.S. Forest Service, SA, S&PF, Forest Insect & Disease Management, Atlanta, GA.

A state game biologist made pre- and post-treatment observations for any unusual mortality in mammal and reptile populations. Again, this report was negative for both treatments.

Federal fish and wildlife biologists took samples of birds, mammals, and reptiles from the areas both pre- and post-treated. Tissues from these animals are to be analyzed for trichlorfon residues or examined for gross organ pathologies attributable to B.t. These analyses are not yet complete.

A turkey impact study was conducted by Auburn University wildlife personnel. Larvae killed by each material were collected in the treated areas following treatment, frozen, and returned to Auburn. There they were thawed and force fed to turkeys in large volumes. No acute toxicity was noted following these feedings.

A study of the effects of trichlorfon on immature marine Crustacea (shrimp and crab) and oysters was planned, but was not conducted by the Alabama State Marine Biology Laboratory due to insufficient funds.

Auburn University fisheries personnel conducted studies on the effects of B.t. and trichlorfon on fish food organisms in the test areas. Plate samplers were placed in each plot prior to spraying so that resident populations of phytoplankton, zooplankton, small crustaceans and aquatic insects could colonize on their surfaces. Plates were removed either immediately before or at intervals following treatments.

Preliminary examination of the data indicates that in no case was any change in types or numbers of organisms caused which would be attributed to the treatments. There was an indication that chironomid or midge larvae may have been reduced in waters receiving B.t., but low sample numbers and midge distribution patterns do not allow any confidence to be placed in these results until further data is obtained.

The effect of treatments on non-target insects in the tree canopies was monitored by placing traps under the treated trees. Samples collected from these traps are being sorted and identified at present. Preliminary results indicate that there were significantly higher losses of certain groups of insects and spiders in the canopy of the trichlorfon treated area than in the B.t. or control areas. Most of the B.t. killed insects were non-target caterpillars.

Table 1: Average mean percent estimated defoliation by forest tent caterpillar on water tupelo before and after treatment, Mobile-Tensaw River Basin, Alabama, 1975.

| Treatment | Date of Estimation 1 (3/25) | (3/28) | 2 (4/1) | 3 (4/9) | 4 (4/15) | 5 (4/22) | 6 (4/30) |
|---|---|---|---|---|---|---|---|
| Dylox | 41±21[1/] | | 52±17 | 43±19 | 39±15 | 35±15 | 19±11 |
| Dipel I | 38±18 | 65±23[2/] | 77±23 | 81±23 | 86±21 | 84±23 | 77±30 |
| Dipel II | 35±19 | | 58±22[3/] | 63±26 | 64±25 | 54±26 | 44±26 |
| Control | 34±24 | | 87±12 | 97±4 | 99±.8 | 99±.7 | 99±[4/] |

1/ Dylox treatment applied 3/26.

2/ Dipel treatment applied 3/31.

3/ Second Dipel treatment applied 4/7.

4/ Individual tree defoliation not estimated.

Table 2: Spray deposit on Tupelo leaves taken from one branch samples in the plot treated with trichlorfon in the Mobile Basin, Alabama, 1975.

| Sub-plot | No. drops/4 sq. cm. on each of 10 leaves | | | | | | | | | | Total | Ave. no. drops per sq. cm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| A | 2 | 12 | 2 | 0 | 21 | 3 | 13 | 4 | 1 | 0 | 55 | 1.38 |
| B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.02 |
| D | 2 | 0 | 5 | 1 | 2 | 2 | 0 | 1 | 2 | 0 | 15 | 0.38 |
| E | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 5 | 0.12 |
| F | 1 | 3 | 1 | 0 | 3 | 2 | 12 | 1 | 0 | 0 | 23 | 0.58 |
| G | 1 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 9 | 0.22 |
| H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| J | 5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 10 | 0.25 |
| K | 2 | 1 | 8 | 2 | 1 | 6 | 22 | 0 | 1 | 10 | 53 | 1.32 |
| L | 1 | 0 | 5 | 0 | 0 | 2 | 5 | 0 | 0 | 0 | 13 | 0.32 |
| M | 5 | 16 | 2 | 13 | 26 | 2 | 6 | 10 | 27 | 8 | 115 | 2.88 |
| N | 2 | 7 | 1 | 4 | 10 | 27 | 26 | 25 | 9 | 11 | 122 | 3.05 |
| O | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 9 | 0.22 |
| P | 23 | 18 | 4 | 34 | 29 | 15 | 21 | 11 | 2 | 28 | 185 | 4.62 |
| Q | 8 | 11 | 8 | 1 | 3 | 1 | 5 | 4 | 0 | 6 | 47 | 1.18 |
| R | 4 | 9 | 14 | 8 | 6 | 22 | 10 | 6 | 9 | 5 | 93 | 2.32 |
| S | 0 | 3 | 0 | 0 | 7 | 1 | 0 | 19 | 0 | 2 | 32 | 0.80 |
| T | 0 | 0 | 0 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 9 | 0.22 |
| | | | | | | | | | | Plot | 796 | 1.00 |

Table 3: Percent defoliation estimated for each subplot in area treated with Dylox in Mobile-Tensaw River Basin, Alabama, 1975. 1/

Plot treated March 26, 1975.

| | Date of Estimation | | | | | |
|---|---|---|---|---|---|---|
| | 3/24 | 4/1 | 4/8 | 4/15 | 4/21 | 4/30 |
| A | 38.3 | 45.0 | 40.0 | 36.7 | 26.7 | 13.3 |
| B | 35.0 | 53.3 | 35.0 | 36.7 | 36.7 | 15.0 |
| C | 43.3 | 48.3 | 45.0 | 53.3 | 58.3 | 41.7 |
| D | 10.0 | 32.5 | 10.0 | 27.5 | 15.0 | 7.5 |
| E | 30.0 | 35.0 | 20.0 | 26.7 | 23.3 | 15.0 |
| F | 23.3 | 43.3 | 33.3 | 25.0 | 35.0 | 8.3 |
| G | 60.0 | 53.3 | 40.0 | 38.3 | 36.7 | 17.5 |
| H | 21.7 | 33.3 | 20.0 | 21.7 | 13.3 | 8.3 |
| I | 43.3 | 75.0 | 65.0 | 61.7 | 48.3 | 26.7 |
| J | 56.7 | 60.0 | 53.3 | 51.7 | 46.7 | 11.7 |
| K | 46.7 | 66.7 | 53.3 | 43.3 | 38.3 | 23.3 |
| L | 25.0 | 38.3 | 25.0 | 26.7 | 36.7 | 43.3 |
| M | 38.3 | 53.3 | 45.0 | 28.3 | 28.3 | 10.0 |
| N | 60.0 | 61.7 | 50.0 | 46.7 | 41 7 | 16.7 |
| O | 88.3 | 93.3 | 90.0 | 73.3 | 61.7 | 31.7 |
| P | 25.0 | 46.7 | 43.3 | 28.3 | 26.7 | 11.7 |
| Q | 23.3 | 36.7 | 38.3 | 26.7 | 18.3 | 11.7 |
| R | 10.0 | 20.0 | 25.0 | 15.0 | 10.0 | 8.3 |
| S | 63.3 | 66.7 | 66.7 | 60.0 | 56.7 | 36.7 |
| T | 75.0 | 66.7 | 55.0 | 45.0 | 43.3 | 13.3 |
| Average: | 41.9 | 52.3 | 43.53 | 39.3 | 35.0 | 18.6 |
| Average $\bar{x}$ | 40.8 | 51.46 | 42.66 | 38.6 | 35.9 | 19.0 |
| S $x$ | 21.16 | 17.28 | 18.72 | 15.33 | 14.99 | 11.42 |

1/ Average defoliation of the three sample trees in each subplot.

*Table 4:* *Spray deposit on Tupelo leaves taken from one branch samples in the plot treated with Bacillus thuringiensis in the Mobile Basin, Alabama, 1975.*

| Sub-plot | No. drops/4 sq. cm. on each of 10 leaves | | | | | | | | | | Total | Ave. no. d per sq. cm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| A | | | | | | | | | | | | |
| B | | | | | NO | SA | MP | LE | S | | | |
| C | | | | | | | | | | | | |
| D | | | | | | | | | | | | |
| E | 14 | 49 | 35 | 13 | 57 | 50 | 1 | 56 | 50 | 1 | 326 | 8.15 |
| F | 7 | 1 | 6 | 10 | 10 | 7 | 4 | 4 | 11 | 9 | 69 | 1.72 |
| G | 9 | 5 | 3 | 7 | 4 | 1 | 1 | 4 | 5 | 3 | 42 | 1.05 |
| H | 0 | 1 | 2 | 0 | 2 | 2 | 3 | 2 | 4 | 0 | 16 | 0.40 |
| I | 7 | 0 | 3 | 8 | 3 | 5 | 3 | 2 | 5 | 8 | 44 | 1.10 |
| J | 103 | 95 | 39 | 87 | 88 | 22 | 71 | 99 | 138 | 83 | 825 | 20.62 |
| K | 2 | 5 | 3 | 0 | 13 | 0 | 2 | 1 | 5 | 0 | 31 | 0.78 |
| L | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 4 | 9 | 0.22 |
| M | 3 | 23 | 9 | 7 | 10 | 0 | 6 | 6 | 3 | 10 | 77 | 1.92 |
| N | 47 | 6 | 17 | 35 | 44 | 22 | 12 | 16 | 15 | 2 | 216 | 5.40 |
| O | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P | 4 | 6 | 3 | 4 | 7 | 4 | 2 | 3 | 4 | 2 | 39 | 0.98 |
| Q | 7 | 49 | 5 | 0 | 1 | 0 | 21 | 2 | 22 | 25 | 132 | 3.30 |
| R | 122 | 121 | 59 | 21 | 34 | 14 | 142 | 31 | 39 | 87 | 670 | 16.80 |
| S | 31 | 29 | 34 | 21 | 5 | 1 | 24 | 28 | 20 | 12 | 205 | 5.12 |
| T | 5 | 6 | 14 | 7 | 4 | 5 | 4 | 10 | 3 | 1 | 59 | 1.48 |
| T | 6 | 20 | 14 | 4 | 14 | 12 | 1 | 4 | 7 | 1 | 83 | 2.08 |
| | | | | | | | | | | Plot | 2826 | 4.16 |

Table 5: Percent defoliation estimated for each subplot in area treated one time with Dipel in Mobile-Tensaw River Basin, Alabama, 1975. 1/

Plot treated March 31, 1975.

| | Date of Estimation | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3/25 | 3/28 | 4-1 | 4-9 | 4-15 | 4-22 | 4-29 |
| A | 5.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| B | 45.0 | 80.0 | 95.0 | 98.0 | 98.0 | 96.5 | 90.0 |
| C | 15.0 | 63.3 | 68.3 | 66.0 | 66.0 | 55.0 | 23.3 |
| D | 13.3 | 26.6 | 43.3 | 56.6 | 83.3 | 91.6 | 98.0 |
| E | 35.0 | 61.6 | 81.6 | 68.3 | 68.3 | 45.0 | 11.6 |
| F | 46.6 | 90.0 | 90.0 | 93.6 | 91.0 | 77.6 | 70.0 |
| G | 46.6 | 76.3 | 88.3 | 95.3 | 97.3 | 96.6 | 98.3 |
| H | 36.6 | 73.3 | 93.3 | 97.0 | 93.6 | 96.6 | 98.3 |
| I | 16.6 | 33.3 | 41.6 | 45.0 | 73.3 | 81.0 | 90.0 |
| J | 65.0 | 91.6 | 93.3 | 96.3 | 97.0 | 95.0 | 95.0 |
| K | 30.0 | 46.6 | 63.3 | 91.6 | 98.0 | 100.0 | 100.0 |
| L | 35.0 | 41.6 | 66.6 | 82.0 | 97.0 | 100 0 | 100.0 |
| M | 35.0 | 68.3 | 85.0 | 86.6 | 86.6 | 88.3 | 77.6 |
| N | 46.6 | 75.0 | 95.0 | 97.0 | 96.0 | 97.6 | 94.3 |
| O | 55.0 | 88.3 | 93.3 | 98.0 | 98.0 | 100.0 | 100.0 |
| P | 45.0 | 64.3 | 86.0 | 89.3 | 91.0 | 86.6 | 68.3 |
| Q | | | | | | | |
| R | 36.6 | 80.0 | 86.6 | 91.6 | 91.0 | 90.0 | 80.0 |
| S | 46.6 | 65.0 | 77.6 | 78.6 | 81.0 | 81.6 | 66.6 |
| T | 66.6 | 95.0 | 95.0 | 98.0 | 98.0 | 97.6 | 76.6 |
| Average: | 39.07 | 66.57 | 78.72 | 83.37 | 87.33 | 86.01 | 78.42 |
| Average $\bar{x}$: | 37.95 | 64.74 | 76.47 | 80.98 | 86.02 | 83.50 | 76.20 |
| S $x$: | 17.65 | 23.50 | 23.06 | 23.13 | 20.87 | 23.26 | 29.61 |

1/ Average of the three sample trees in each subplot.

Table 6: Percent defoliation estimated for each subplot in area treated twice with Dipel in Mobile-Tensaw River Basin, Alabama, 1975.1/

Plot treated March 31 & April 7, 1975.

| | Date of Estimation | | | | | |
|---|---|---|---|---|---|---|
| | 3/25 | 4/1 | 4-9 | 4-15 | 4-22 | 4-29 |
| A | 20.0 | 46.6 | 40.0 | 36.6 | 18.3 | 10.0 |
| B | 28.3 | 45.0 | 48.3 | 53.3 | 48.3 | 15.0 |
| C | 38.3 | 63.3 | 50.0 | 55.0 | 56.6 | 26.6 |
| D | 10.0 | 15.0 | 16.6 | 23.3 | 15.0 | 10.0 |
| E | 46.6 | 86.6 | 90.0 | 88.3 | 76.6 | 51.6 |
| F | 11.6 | 38.3 | 36.6 | 50.0 | 35.0 | 36.6 |
| G | 50.0 | 75.0 | 92.0 | 93.3 | 88.3 | 88.3 |
| H | 46.6 | 68.3 | 87.6 | 89.3 | 88.3 | 86.6 |
| I | 58.3 | 71.6 | 89.3 | 92.6 | 86.6 | 83.3 |
| J | 20.0 | 61.6 | 41.6 | 65.0 | 35.0 | 20.0 |
| K | 15.0 | 63.3 | 58.3 | 48.3 | 46.6 | 31.6 |
| L | 10.0 | 23.3 | 33.3 | 31.6 | 30.0 | 30.0 |
| M | 25.0 | 33.3 | 28.3 | 30.0 | 18.3 | 15.0 |
| N | 66.6 | 71.6 | 70.0 | 75.0 | 38.3 | 31.6 |
| O | 56.6 | 85.0 | 86.6 | 86.6 | 70.0 | 46.6 |
| P | 58.3 | 88.3 | 86.0 | 89.3 | 80.0 | 76.6 |
| Q | 16.6 | 38.3 | 40.0 | 33.3 | 33.3 | 36.6 |
| R | 56.6 | 86.6 | 92.6 | 89.3 | 83.3 | 68.3 |
| S | 38.3 | 40.0 | 90.0 | 83.3 | 80.0 | 70.0 |
| T | 28.3 | 53.3 | 73.3 | 76.6 | 61.6 | 51.6 |
| Average: | 35.08 | 59.41 | 62.63 | 64.53 | 54.50 | 44.33 |
| Average $\bar{x}$: | 35.05 | 57.71 | 62.52 | 64.50 | 54.47 | 44.29 |
| S $x$: | 18.79 | 22.00 | 25.72 | 24.64 | 25.73 | 26.42 |

1/ Average of the three sample trees in each subplot.

Table 7: Percent defoliation estimated for each subplot in control area in Mobile-Tensaw River Basin, Alabama, 1975. 1/

| | Date of Estimation | | | | |
|---|---|---|---|---|---|
| | 3/24 | 4/1 | 4/8 | 4/15 | 4/22 |
| A | 30.0 | 95.0 | 98.0 | 99.0 | 100.0 |
| B | 70.0 | 95.0 | 98.0 | 100.0 | 100.0 |
| C | 38.3 | 93.3 | 97.0 | 100.0 | 100.0 |
| D | 15.0 | 95.0 | 98.0 | 100.0 | 100.0 |
| E | 65.0 | 98.0 | 98.0 | 100.0 | 96.7 |
| F | 20.0 | 91.7 | 95.0 | 98.3 | 99.3 |
| G | 90.0 | 80.0 | 98.0 | 99.3 | 100.0 |
| H | 15.0 | 80.0 | 98.0 | 99.3 | 100.0 |
| I | 25.0 | 80.0 | 98.0 | 98.7 | 100.0 |
| J | 60.0 | 95.0 | 98.0 | 100.0 | 100.0 |
| K | 23.3 | 93.3 | 98.0 | 100.0 | 100.0 |
| L | 46.7 | 93.3 | 98.0 | 100.0 | 100.0 |
| M | 25.0 | 90.0 | 98.0 | 100.0 | 100.0 |
| N | 15.0 | 95.0 | 98.0 | 100.0 | 100.0 |
| O | 18.3 | 75.0 | 98.0 | 98.0 | 100.0 |
| P | 11.7 | 93.3 | 98.0 | 98.6 | 100.0 |
| | 16.7 | 73.3 | 97.0 | 99.3 | 100.0 |
| Q | 6.7 | 66.6 | 82.0 | 98.0 | 100.0 |
| R | 63.3 | 90.0 | 97.0 | 98.0 | 99.0 |
| S | 22.5 | 55.0 | 98.0 | 98.0 | 100.0 |
| Average: | 32.7 | 87.9 | 93.3 | 99.2 | 98.0 |
| Average $\bar{x}$: | 33.8 | 86.3 | 96.9 | 99.2 | 99.7 |
| S $x$: | 23.6 | 11.59 | 96.9 | .83 | .75 |

1/ Average of the three sample trees in each subplot.

## FOOTNOTES

1/ Abrahamson, 1969-1974. Study Plan. Impact of the forest tent caterpillar, Malacosoma disstria Hbn. (Lepidoptera: Lasiocampidae), on bottomland hardwood forests. (Includes yearly establishment reports).

2/ Morris and Abrahamson, 1969. Final Report. Effects of aerially applied ultra low volume insecticides on forest tent caterpillar in coastal gum forests.

3/ Morris and Abrahamson, 1970. Final Report. Control of forest defoliation without damage to wildlife in hardwood bottomlands.

4/ Harper, J.D., 1974-1975, Study Plans - Field testing of microbial and selective chemical insecticides for control of forest tent caterpillar in southeastern Alabama.

5/ Hyland, James, 1974. Aerial survey report on forest tent caterpillar defoliation in Mobile-Tensaw River Basin. Alabama Forestry Commission.

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Ciesla, W.M., L.E. Drake, and D.H. Wilmore. 1971. Color photos, aerial sprays and the forest tent caterpillar. Photogramm. Eng. 39:867-73.

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